TDAQ Upgrade R&D
WBS 4.6

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University of Oregon

Phase-II Construction Managers Meeting
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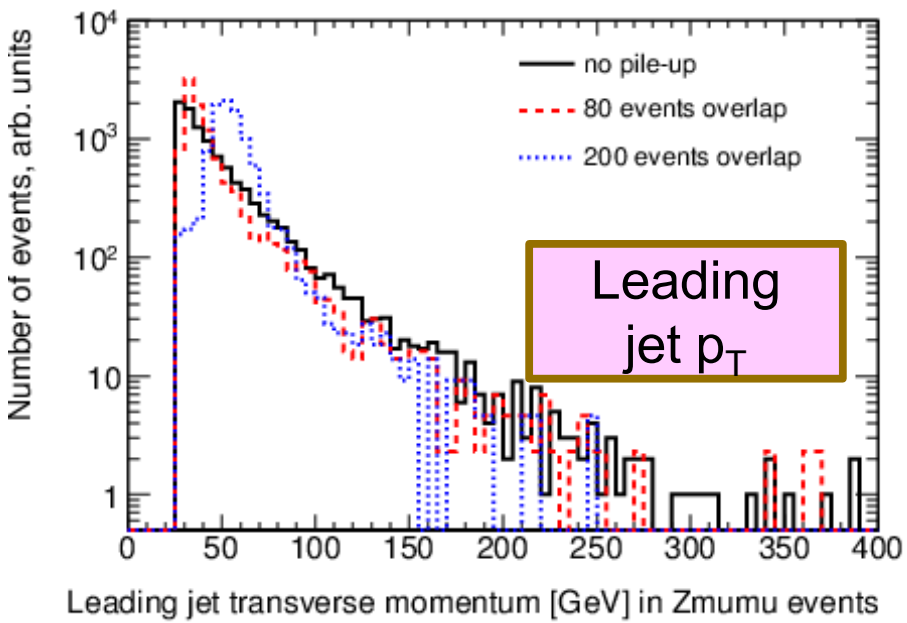
Physics Motivation

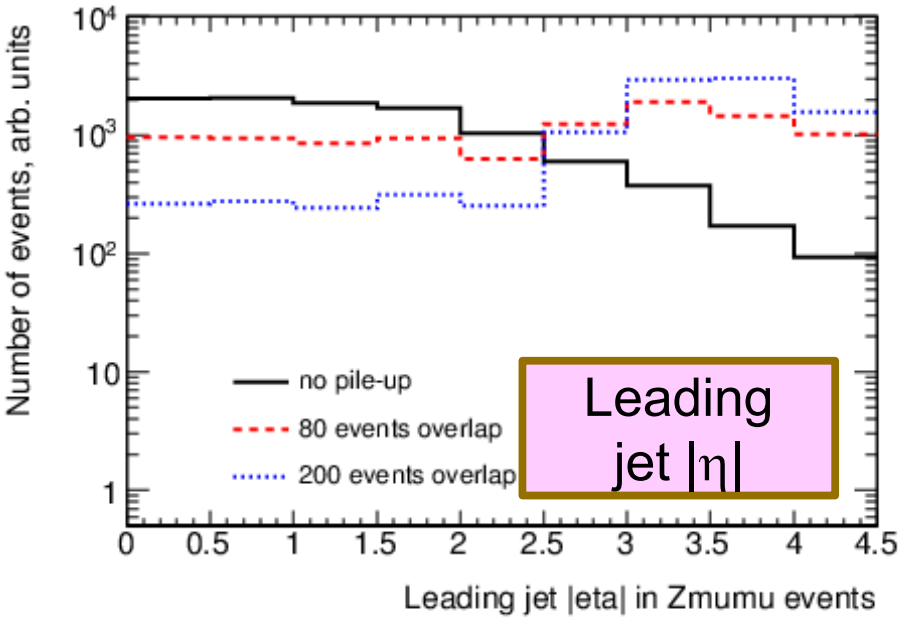
- MET triggers are essential to searches for new physics, in addition to benchmark physics processes
  - Any hint of new physics in Runs 2 or 3 must be investigated in detail & corroborated through complementary channels
- Calorimeter Triggers in Phase-II
  - Pileup mitigation in a harsh environment (up to μ=200) is critical to maintain the MET trigger performance
  - The forward region is particularly challenging
  - L1Global is especially important in the *low* & *middle* scenarios where the L1 rate is limited to 200 kHz
  - **Opportunity for significant performance gains with a modest investment in R&D**

Challenge of Forward Jets

- Forward jets dominate at high pileup

Jet p_T and $|\eta|$-spectra for $Z \rightarrow \mu\mu$ + jets vs μ (offline jets)

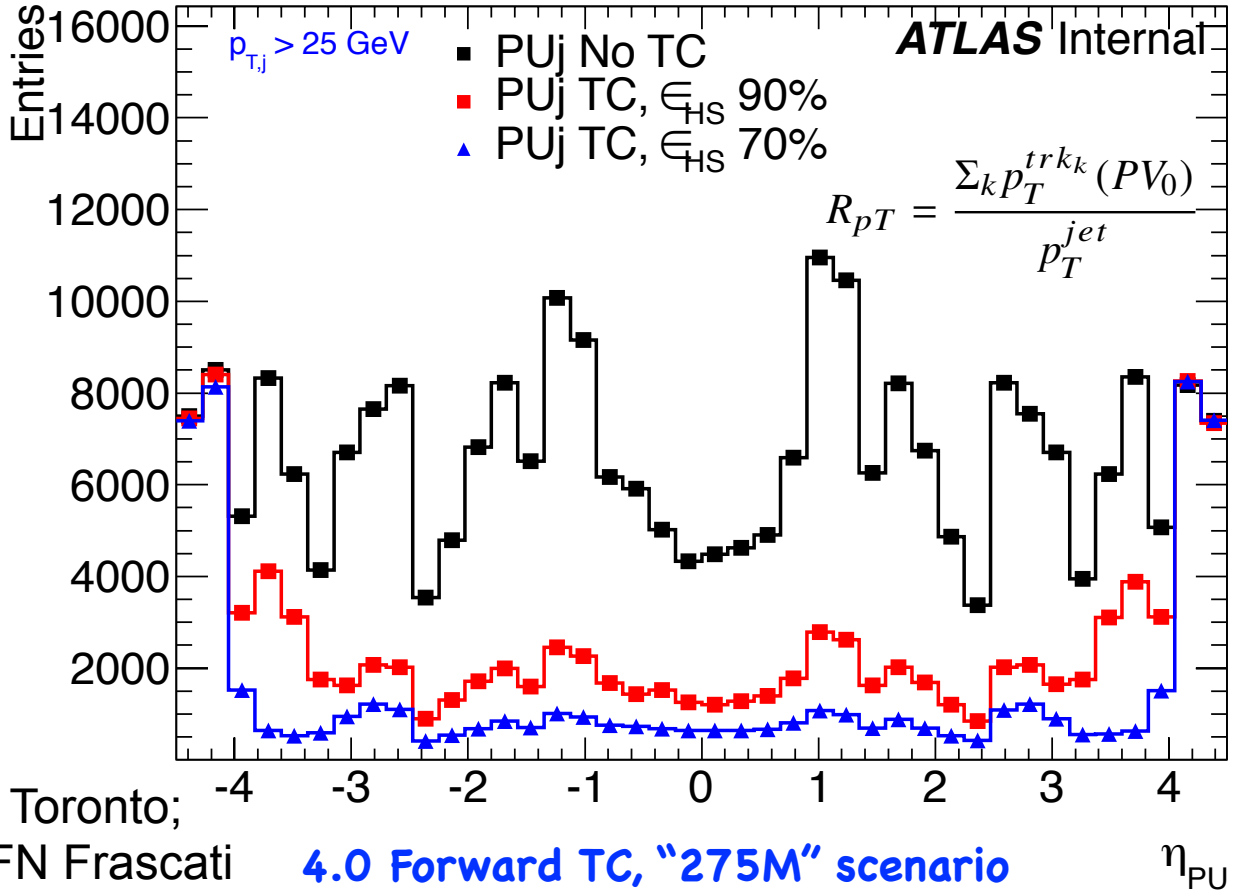




Increase of average jet p_T with μ , no increase of tails
Reason: more pile-up jets in the region $|\eta|>2.5$ not protected by JVF cut

Challenge of Forward Jets

- As soon as the tracking boundary is reached, pileup jets take over (note: plot below is optimistic, does not include edge effects)

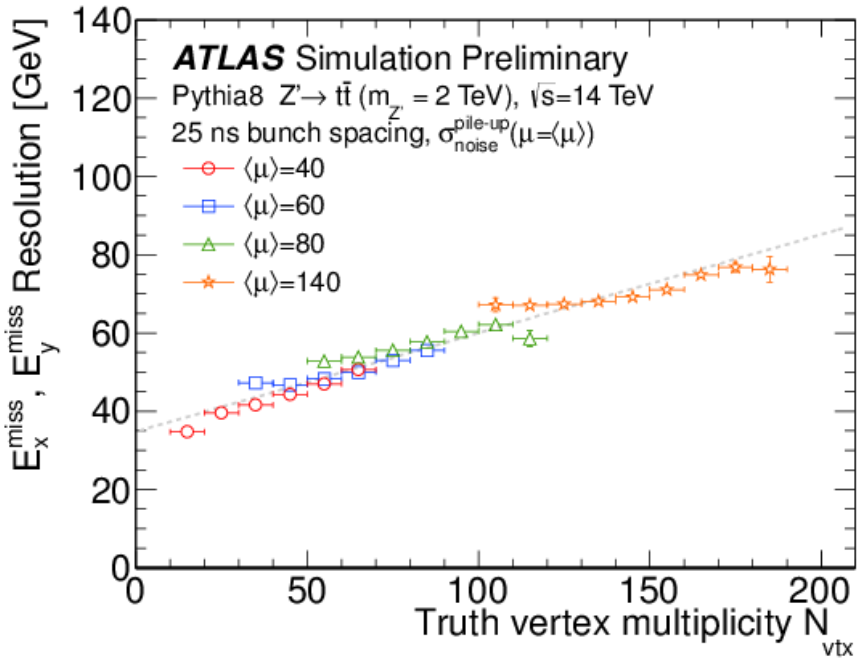


R. Polifka, U Toronto;
M. Testa, INFN Frascati

4.0 Forward TC, "275M" scenario

Topocluster-like Processing

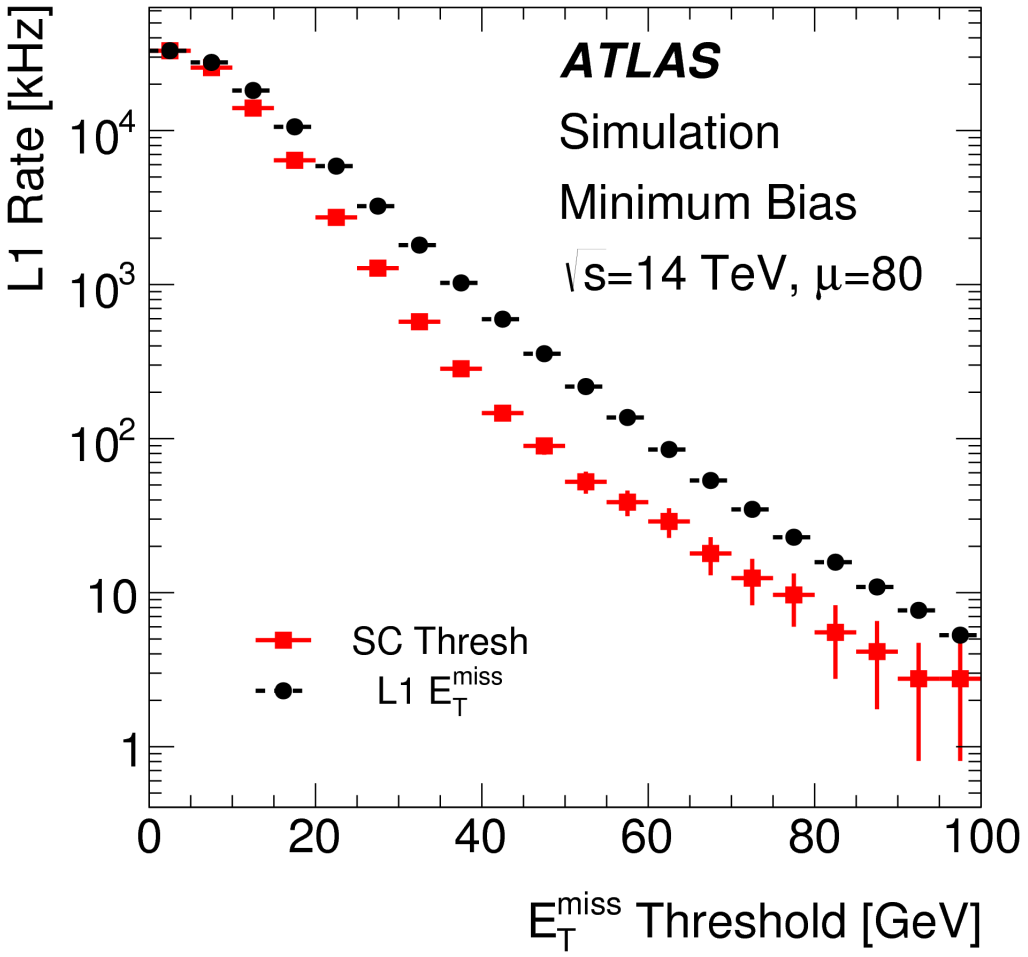
- Topoclustering has proven especially effective against pileup in offline jet reconstruction and in the EF (HLT) in Run 1 (2)
- $E_{x,y}^{miss}$ resolution increases linearly wrt the number of truth vertices, but is **independent of μ**
- σ_{noise} includes electronic ⊕ pile-up



https://twiki.cern.ch/twiki/bin/view/AtlasPublic/JetEtmissApproved2013HighMuEtmiss

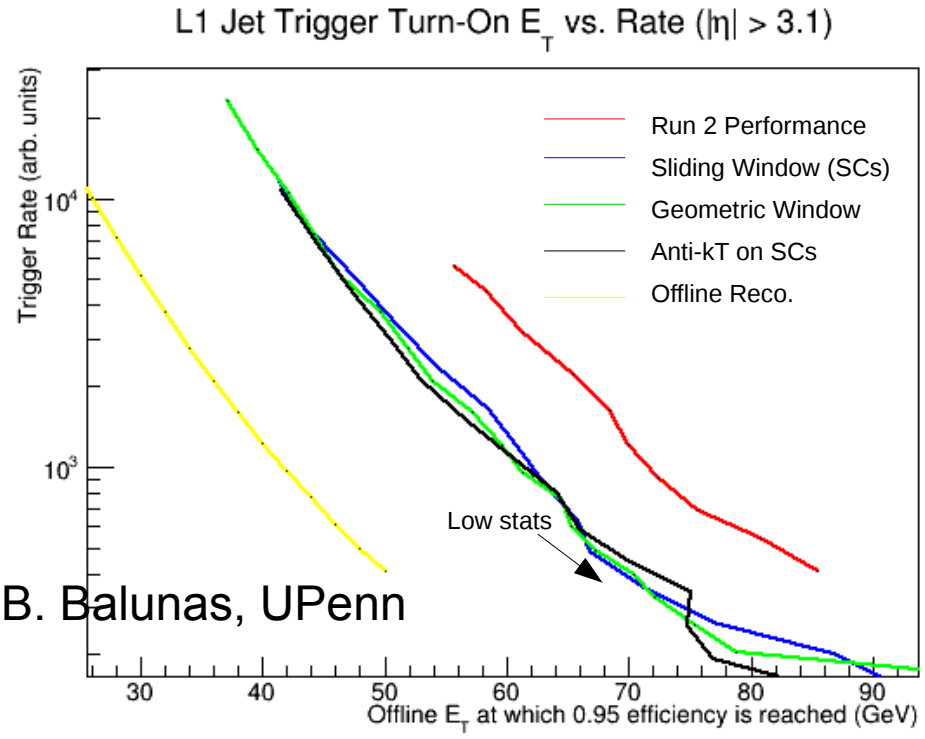
Topocluster-like Processing

- LAr Phase-I TDR Study only includes supercells in MET calculation if middle LAr layer satisfies $|E| > 2\sigma$
- ~20 GeV reduction in MET threshold for same rate ($|\eta| < 4.9$)
- "Easy" to implement in LAr DPS or after L1 Accept, even in Phase I [assuming FPGA resources]

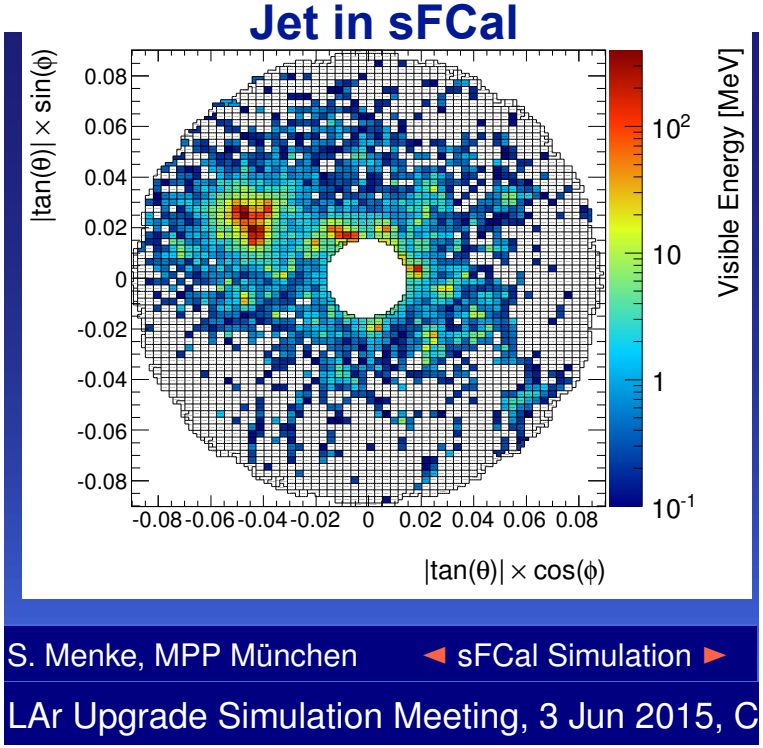


Topoclustering + Forward Jets

- Plenty of room for improvement between expected Run 3 performance and Offline
- Strategy is compatible with a potential finer granularity forward calorimeter (sFCal) and/or a high-granularity timing detector



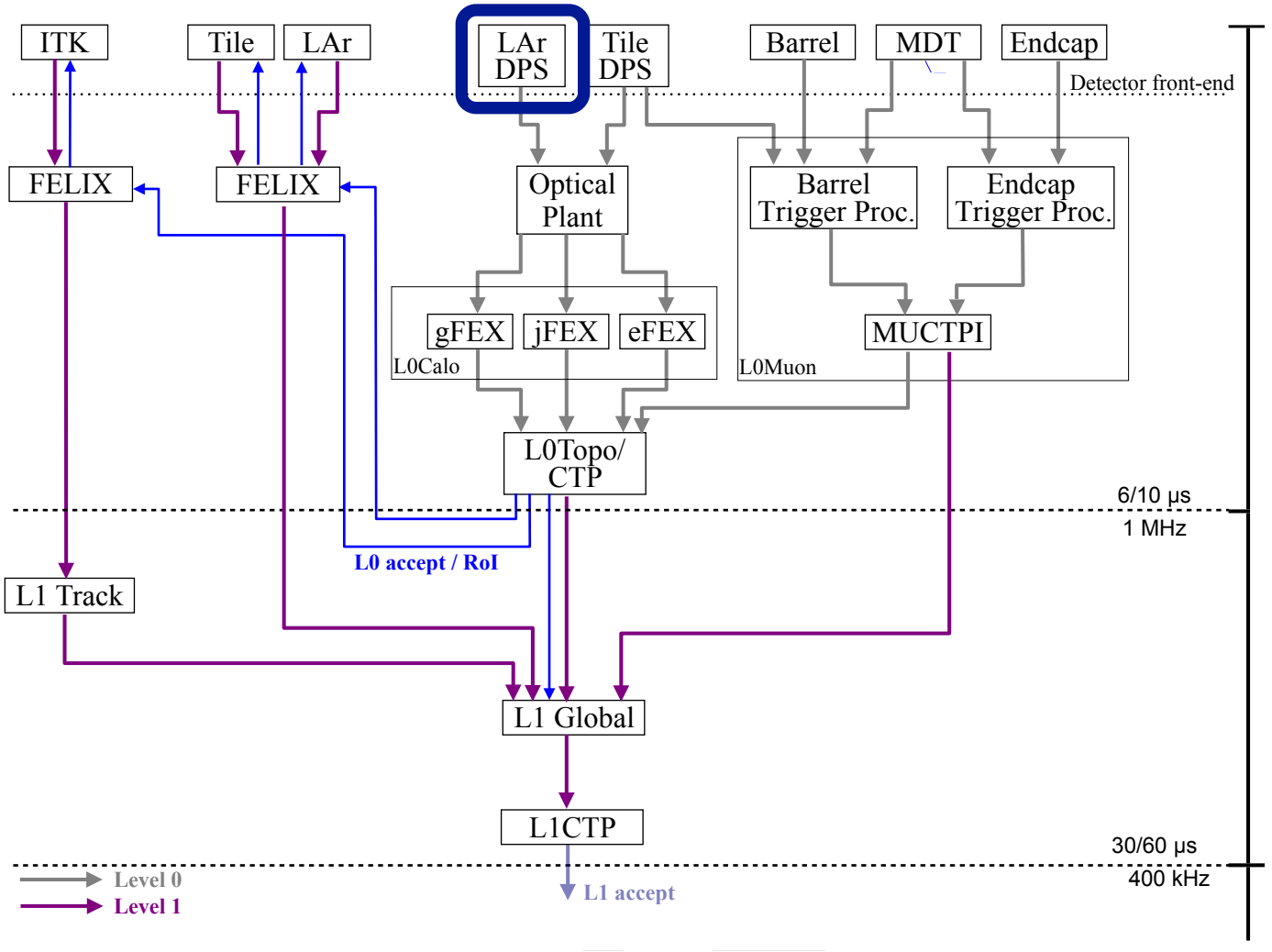
B. Balunas, UPenn



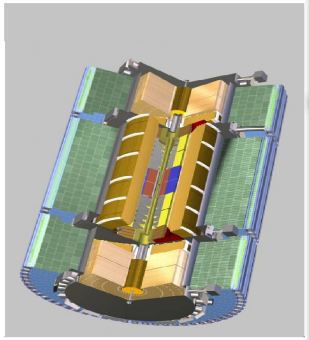
S. Menke, MPP München ◄ sFCal Simulation ►

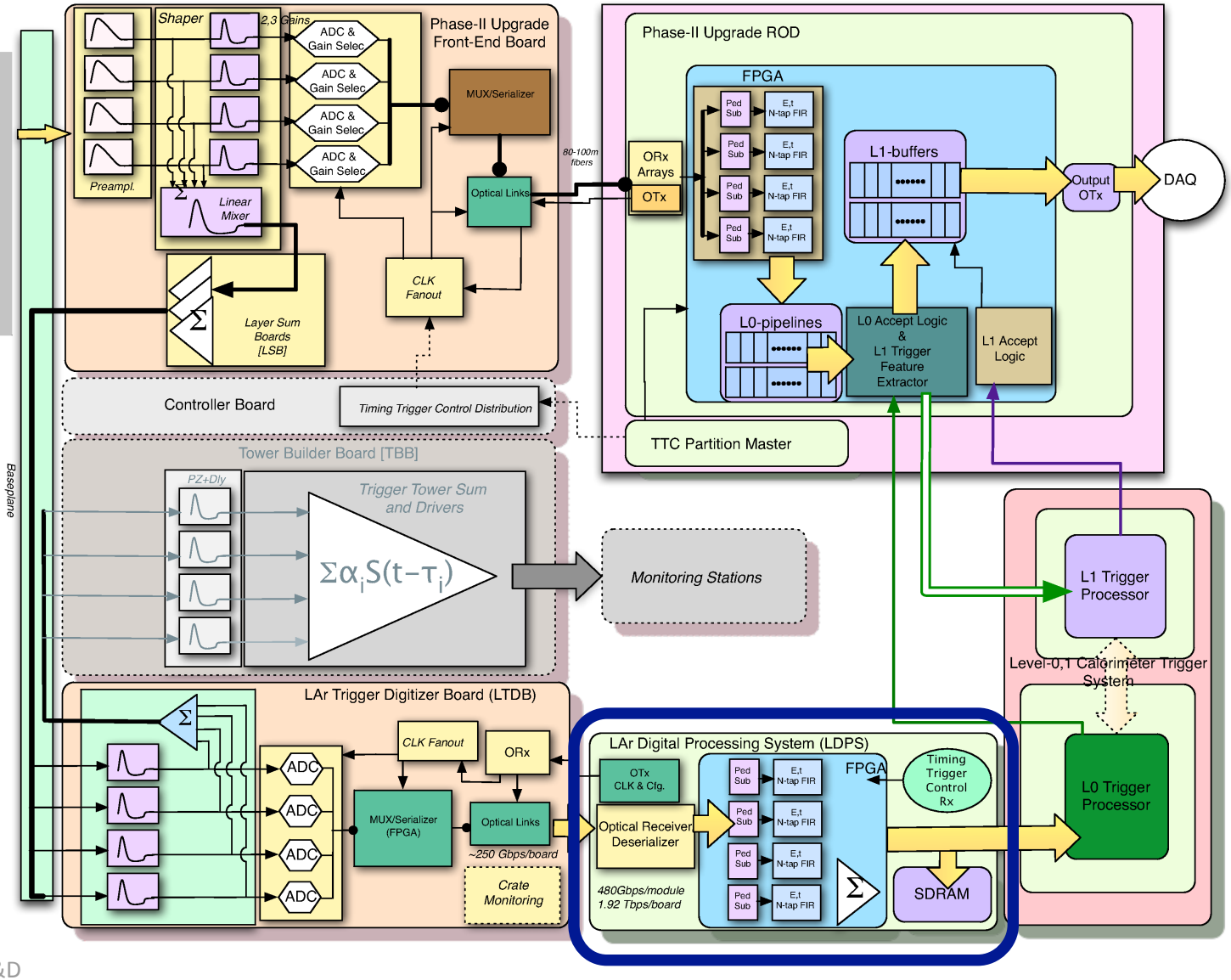
LAr Upgrade Simulation Meeting, 3 Jun 2015, C

Phase-II ATLAS Trigger



LAr Digital Processing System





Possible Implementation(s)

- In LAr DPS: Calculate whether E_T in each cell is above 4σ, 2σ, or 0
- Transmit resulting flagged cells
  - via fiber?
  - over ATCA backplane?
  - to FELIX?

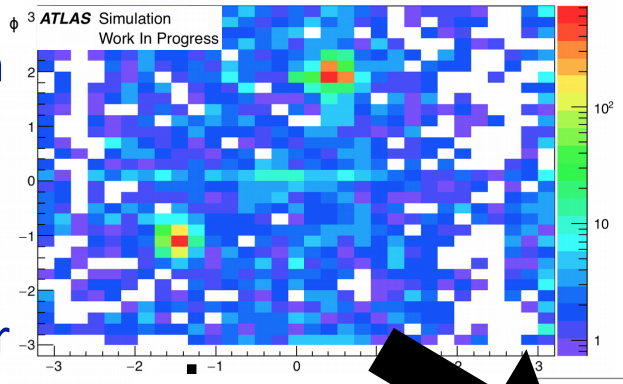
can exploit synergy with US ATLAS TDAQ deliverables from Phase-I Construction Project

- "Clustering algorithm" performed in FPGA, in a dedicated module? superHub? aggregator?
- Benchmark against offline topoclustering
- Main Challenge (reason for R&D):
  - Topoclustering algorithm was developed for offline use on a CPU, and is a **sequential** algorithm
    - ➡ Cannot be implemented `out-of-the-box' in a FPGA
  - Engineering/technical expertise needed for adoption

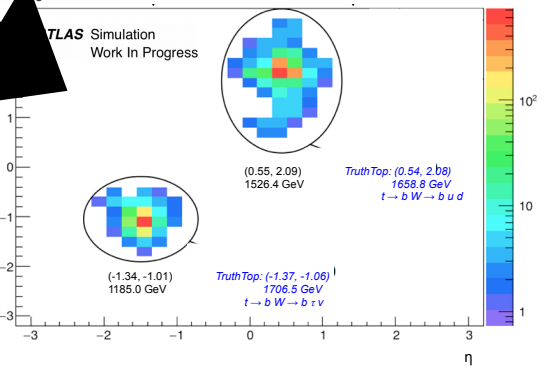
Standalone Algorithm Development

- 2-D topoclustering algorithm implemented in standalone simulation over coarse (0.2x0.2) granularity
- Simple local maximum finder in lieu of split/merge
- Fixed threshold optimization performed; relative threshold (using noise) optimization in progress

Seed Layer (20 GeV) → Local Max Finding → Primary Layer (3 GeV) → Perimeter Layer (1 GeV) → Combine gTowers using 4-vectors

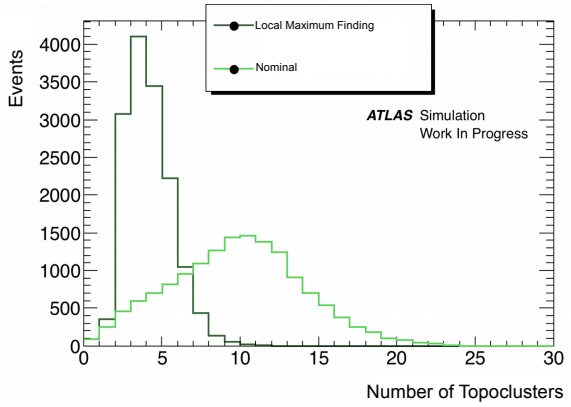


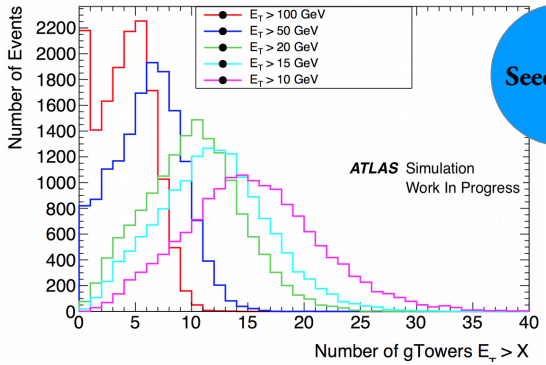
externally funded undergrads:
Luc Lisi,
Elliot Parrish,
Brianna Stamas



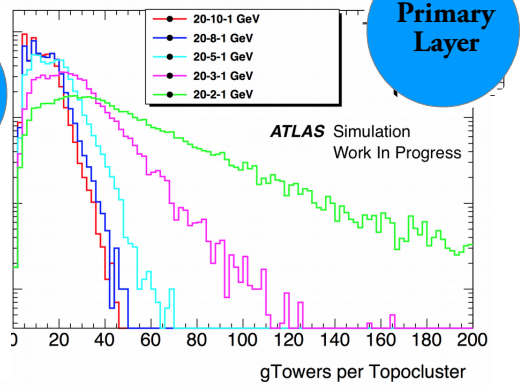
$Z' (5\ TeV) \rightarrow t\bar{t}$

$\langle\mu\rangle = 80$





Seed Layer



Primary Layer

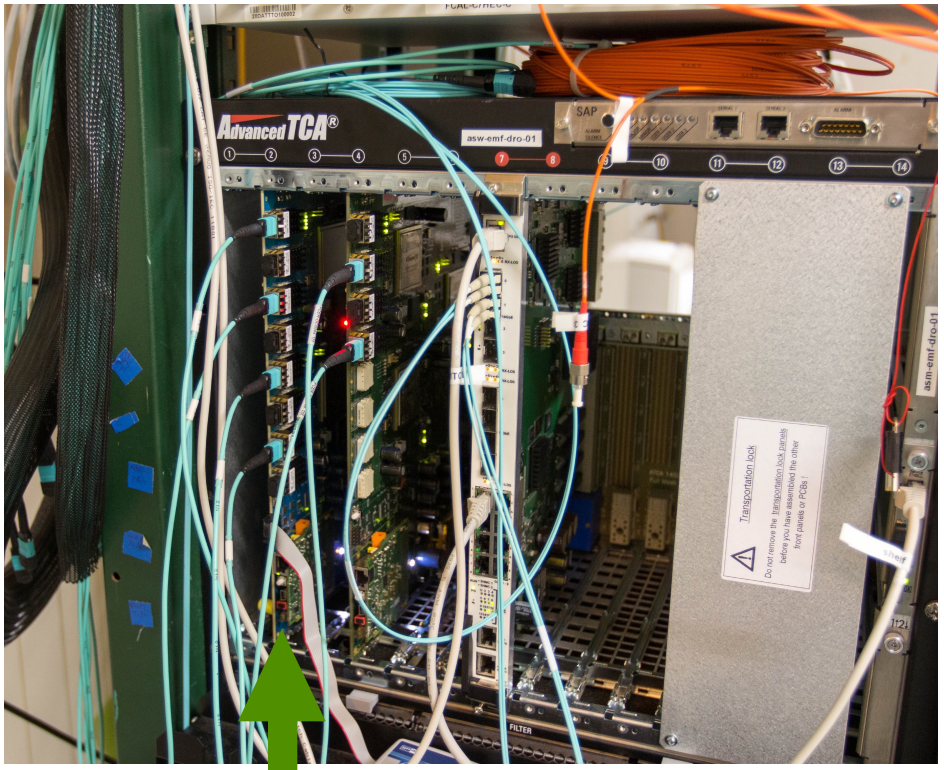
Project Goals / Questions

- Phase-II TDAQ TDR by late 2017
  - L1Global especially important if limited to 200kHz
  - R&D on topoclustering option needed to design the system!
- Outstanding questions
  - Can a clustering-like option (or one with similar performance) be implemented on a FPGA?
  - What is the latency of such an algorithm?
  - What is the optimal granularity to achieve performance goals (& can this be traded for latency?)
- Context within international ATLAS
  - L1Calo community currently occupied by Phase I
  - Results will be presented more frequently within L1Calo Simulation group

LDPS Blade [Demonstrator]

- Oregon LDPS blade has been moved to CERN/EMF to read out second LAr LTDB demonstrator
- Board tested in situ at EMF in June; test FW loaded and fully functional
- Data collection dependent on regional eta-phi selection trigger capability from L1Topo in the region of crate I06:
  $0 < \eta < 1.4$, $9/16\pi < \phi < 11/16\pi$

EMF @ CERN



Oregon LDPS Blade

Status and Milestones

Milestones for 2014/2015

- Install LDPS blade at Oregon ATCA shelf (equipment funded by S. Majewski startup with ATLAS collaborators)
- Develop firmware for reading out demonstrator that will be installed in ATLAS at end of 2014
- Use data playback on test system to test Phase-I/II MET clustering and pile-up corrections
- R&D funds support technician to install + maintain system and firmware (0.33 FTE)
- Algorithm development by externally funded students (0.3-0.5 FTE) and postdocs (0.3-0.5 FTE)

Status and Milestones

❖ Milestones for 2014/2015

- ✓ Install LDPS blade at Oregon ATCA shelf (equipment funded by S. Majewski startup with ATLAS collaborators) + installation @ CERN
- Develop firmware for reading out demonstrator that will be installed in ATLAS at end of 2014
  - basic fw version developed by other groups
- Use data playback on test system to test Phase-I/II MET clustering and pile-up corrections
  - by end of Q2, eng less available (Ph I + future detector R&D); 0.3 FTE for Q4
- R&D funds support technician to install + maintain system and firmware (0.33 FTE)
- ✓ Algorithm development by externally funded students (0.3-0.5 FTE) and postdocs (0.3-0.5 FTE) needs engineering input

Technician hired at 0.3 FTE (+0.2 FTE from CS) for Q4

Milestones for FY16

- Continue algorithm development toward an early proof-of-principle version on a limited eta range and with coarse granularity
  [Q1 FY16, using 0.30 FTE engineer from Q4 FY15 + 0.5 FTE technician + students/postdoc supported by external funds]

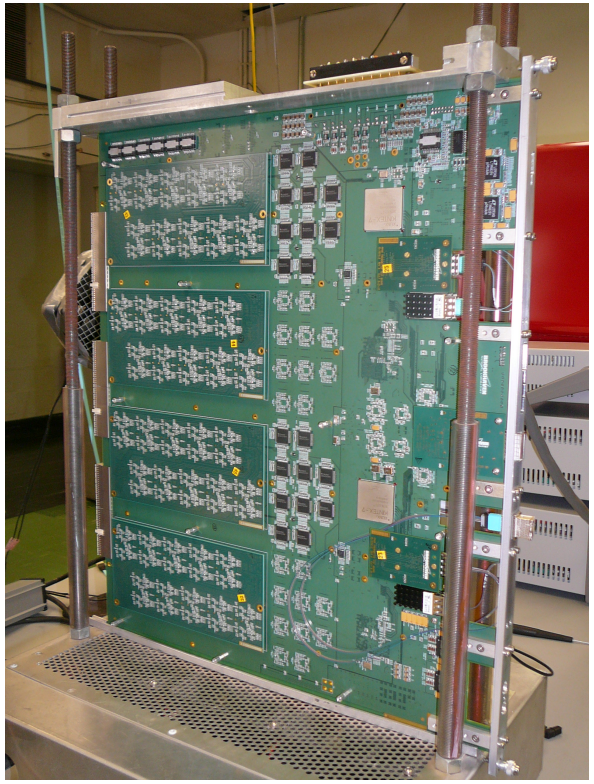
- Develop firmware for reading out demonstrator & algorithm testing (carried over from last year, contingent on L1Topo commissioning)
  [0.25-0.3 FTE engineer in FY16] note: will be descoped without additional support
- Investigate additional algorithm possibilities and finer granularity
  [students/postdoc supported by external funds]

Summary

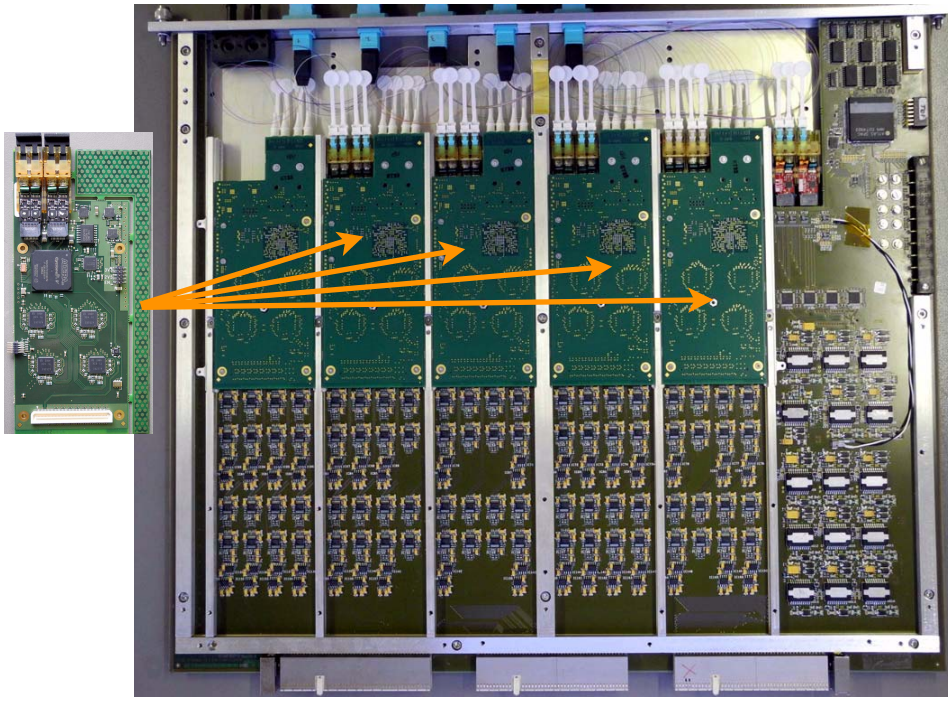
- A plan is needed to maintain the MET trigger performance for the HL-LHC
  - Opportunity to maintain US ATLAS leadership / deliverables in TDAQ
  - R&D required to provide input into the system design for the TDAQ TDR (end 2017)
- Project lies at the intersection between LAr and TDAQ
  - Recognize need to stimulate R&D in this area in US and Int'l LAr +TDAQ communities, improve visibility
  - **Opportunity for significant MET trigger performance gains with a modest investment in R&D**
  - The US is in an excellent position to claim & maintain leadership in this area

2 LTDB demonstrators

- 2 demonstrators installed in Crate I06 in Summer 2014, analog path part of ATLAS trigger system



Digital motherboard, analog mezzanines (see talk by H. Chen): https://indico.cern.ch/event/337396/contribution/7/material/slides/0.pdf



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